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THE NEW INSECTICIDES FOR CONTROLLING EXTERNAL PARASITES OF LIVESTOCK

Compiled by E. F. Knipling,
Division of Insects Affecting Man and Animals

The available information on the insecticidal efficiency and toxicology of new insecticides used for the control of external parasites of livestock has been summarized in two previous issues of this publication (December 1948 and April 1949). They also contained suggestions regarding uses for these new materials. Further information has since been obtained by the Bureau of Entomology and Plant Quarantine, the Bureau of Animal Industry, the Food and Drug Administration, State experiment stations, and others, which has resulted in a number of changes in these suggestions. This publication has therefore been revised again to include the most recent information on the use of DDT, benzene hexachloride, lindane, chlordane, toxaphene, methoxychlor, TDE, and piperonyl butoxide for controlling livestock pests.

The major objectives of this report are (1) to summarize the results of research that has been conducted and, insofar as possible, to compare the performance of the different materials against various livestock pests; (2) to summarize briefly the available knowledge regarding the toxicity of the insecticides to animals, as well as on residues in meat and milk when different insecticides are applied to animals; and (3) to recommend or suggest specific uses and restrictions for the new materials.

Many new insecticides and insecticide preparations are being applied to livestock. It has not been possible to investigate all of them thoroughly for their many potential uses. For this reason it is difficult at this time to determine with finality which materials and formulations will give maximum effectiveness, safety, and economy. Before such conclusions can be reached, consideration must be given to the parasites involved, types and age of animals, methods of application, stability of specific formulations, climatic conditions, and other factors. Further research on the various new materials, including those not recommended at this time, is under way by several agencies, and as more information is obtained, changes in recommendations or suggestions may become necessary or desirable.

RESULTS OF TESTS WITH VARIOUS NEW INSECTICIDES

In this paper the performance of DDT will not be discussed under a separate heading. Most of the information obtained by various investigators on this insecticide has been published. However, DDT will serve as a basis of comparison for the performance of other new insecticides.

Benzene Hexachloride and Lindane

Technical benzene hexachloride consists of several isomers. All the isomers are crystalline products. The gamma isomer is the most effective against insects and other external parasites. When benzene hexachloride first became commercially available, most manufacturers formulated insecticides made from a technical product containing 10 to 12 percent of the gamma isomer. The 50-percent benzene hexachloride wettable powder therefore contained 5 to 6 percent of the gamma isomer. Recently there has been a trend in industry to produce benzene hexachloride of higher gamma content, and some manufacturers now have a product containing 36 to 40 percent of the gamma isomer. One containing 95 percent of the gamma isomer was also available experimentally for some time. However, for about 2 years the almost pure gamma isomer has been on the market under the common name "lindane." Although more costly than the technical material, this product has several advantages and its use for livestock pests is encouraged by the Bureau. Most of the research on benzene hexachloride insecticides during this period has been with lindane.

The Bureau's tests have been chiefly with the wettable powders and emulsifiable concentrates containing xylene. In general both types of formulations have been equally effective. Tests with benzene hexachloride products of varying gamma-isomer content have been made against a number of livestock pests. It appears that the insecticidal effectiveness is due almost entirely to the gamma isomer.

The technical product as manufactured has a persistent musty odor, but with the development of lindane the objectionable odor has been largely overcome.

In the discussion of tests with benzene hexachloride insecticides the concentrations are, for the most part, given in terms of the gamma isomer whether different types of the technical product or lindane were used.

Cattle Lice

From the standpoint of initial killing action, benzene hexachloride is one of the most effective insecticides for controlling lice on cattle. It kills the eggs as well as the motile forms by contact, and it also acts as a fumigant. Complete ovicidal effect requires a gamma concentration

of 0.1 percent. It is likely that lower concentrations, as used for control of the motile forms, will not kill a high percentage of the eggs.

Benzene hexachloride has been tested against the short-nosed cattle louse (Haematopinus eurysternus (Nitz.)), the long-nosed cattle louse (Linognathus vituli (L.)), and the cattle tail louse (H. quadripertusus Fahrenh.). Complete control of the first two species was obtained when animals were thoroughly treated with wettable-powder sprays containing 0.06 percent of the gamma isomer. A single thorough treatment with a spray containing 0.03 percent of the gamma isomer in either low gamma or lindane grades has given good control, but in tests conducted in Texas this concentration did not always give complete control. Both concentrations have given good initial control of the cattle tail louse in a limited number of tests. Apparently complete control of this species has been obtained with a spray containing 0.12 percent of the gamma isomer.

Goat Lice

Benzene hexachloride dips made with wettable powders and emulsion concentrates have been tested against red and yellow lice (Bovicola spp.) on Angora goats. At 0.025 percent of the gamma isomer a single dipping eliminated lice from the herd. Excellent initial control was obtained with 0.006-percent dips, but several months after treatment a few lice were present. DDT dips at 0.2- and 0.25-percent concentrations have given complete control of these lice.

Hog Louse

Benzene hexachloride is also effective against the hog louse (Haematopinus adventicius Neum.). A single thorough treatment with a wettable-powder spray containing 0.025 percent of the gamma isomer has given good but not complete control in a limited number of tests. Other workers have reported complete control at 0.05- and 0.06-percent concentrations.

Sheep Tick

In Oregon benzene hexachloride wettable-powder dips containing approximately 0.006, 0.025, and 0.06 percent of the gamma isomer have provided complete control of the sheep tick (Melophagus ovinus (L.)). Thorough treatments with wettable-powder sprays containing 0.025 to 0.05 percent of the gamma isomer (4 to 6 quarts per mature sheep with long fleece) were effective in limited tests, although complete control was not attained until several weeks after treatment. However, ground derris (rotenone 5 percent), at rates of 4 and 8 ounces in 100 gallons of dip, also gave complete control, and this seems to be the most economical treatment for controlling this pest.

Lone Star Tick

Benzene hexachloride sprays made with wettable powders and emulsion concentrates have been tested against the lone star tick (Amblyomma americanum (L.)) on cattle at gamma-isomer concentrations from 0.012 to 0.18 percent. All stages of the tick have been killed with as little as 0.03 percent of the gamma isomer. However, even at 0.18 percent the residual action has not been marked. At Kerrville, Tex., a 0.06-percent spray protected animals for about 4 days, but after 1 week some ticks began to engorge. Concentrations higher than 0.06 percent did not seem to prolong the protection to any marked degree. In comparative tests DDT failed to kill all engorged ticks at a concentration as high as 1.5 percent. However, DDT provided better protection against reinfestation than did benzene hexachloride. The control obtained with sprays containing 0.5 and 0.75 percent of DDT after 2 weeks was comparable with that obtained after 1 week with 0.06 percent of the gamma isomer. The 0.75-percent DDT spray provided 75 percent control after 2 weeks. In view of the initial action of benzene hexachloride and the residual action of DDT, much of the research on ticks has been conducted with a mixture of these insecticides. Concentrations of 0.025 percent of the gamma isomer and 0.5 percent of DDT have been employed.

Winter Tick

Sprays containing benzene hexachloride have been tested on cattle and sprays or washes on horses for control of the winter tick (Dermacentor albipictus (Pack.)) in the vicinity of Kerrville. Good control of all stages was obtained with a gamma-isomer concentration as low as 0.012 percent. Concentrations of 0.03 and 0.06 percent protected animals against reinfestation for about 2 weeks. DDT emulsions and wettable-powder sprays failed to kill all engorged ticks at concentrations up to 2.5 percent, but 0.5- to 0.75-percent concentrations provided protection for about 4 weeks. Mixtures of benzene hexachloride and DDT as used for the lone star tick provided an excellent control for the winter tick.

Ear Tick

In laboratory and field tests benzene hexachloride was effective against the ear tick (Otobius megnini (Duges)) when applied as a spray. Sprays containing 0.025 and 0.03 percent of the gamma isomer plus 0.5 percent of DDT have given good control for 2 to 3 weeks. The Bureau of Animal Industry (Farmers' Bulletin No. 980, The Spinose Ear Tick and Methods of Treating Infested Animals) has shown that benzene hexachloride in a pine oil-xylene solution will control this parasite.

Gulf Coast Tick

Tests against the Gulf Coast tick (Amblyomma maculatum Koch) indicate that benzene hexachloride is about as effective against this species as against the lone star tick, and that mixtures containing 0.025 percent of the gamma isomer and 0.5 percent of DDT will give good control of this species for 2 to 3 weeks.

Flies

Benzene hexachloride is highly toxic to the horn fly (Siphona irritans (L.)) and the house fly (Musca domestica L.). Sprays at gamma concentrations of 0.025 and 0.05 percent applied on cattle for the control of horn flies generally become ineffective in 4 to 14 days, as compared with 3 to 4 weeks for 0.5-percent DDT. In laboratory tests conducted at Orlando, Fla., deposits of technical benzene hexachloride or lindane containing approximately 25 to 50 mg. of the gamma isomer per square foot gave nearly complete control of house flies exposed for 2 hours as long as 9 weeks after treatment. DDT applied at 50 mg. per square foot was completely effective at the end of 36 weeks against flies of normal susceptibility. DDT-resistant house flies showed only slight resistance to benzene hexachloride, and in field tests good results were obtained for 2 to 6 weeks with lindane applied at the rate of 25 to 50 mg. per square foot. However, lindane and other benzene hexachloride insecticides do not possess the long-lasting residual killing power formerly obtained with DDT. Although DDT-resistant flies are susceptible to lindane and benzene hexachloride, there are indications that resistance to these materials may also become a serious problem.

Benzene hexachloride has been reported to provide some control of horse flies and deer flies. In tests conducted in Texas against Tabanus abactor Philip, most of the flies feeding on cattle 1 day after treatment were killed. However, the spray contained approximately 0.25 percent of the gamma isomer. Tests against mixed species near Silsbee, Tex., showed no mortality of flies feeding on cattle 24 hours after treatment with sprays containing 0.15 percent of lindane. In Georgia some success against tabanids was indicated with mixtures of benzene hexachloride and methoxychlor. However, further tests in this area are necessary to determine whether such treatment offers practical control.

Screw-Worm and Fleece Worms

Benzene hexachloride is highly effective as a larvicide for the screw-worm (Callitroga americana (C. and P.)) and fleece worms (Phormia regina (Meig.) and other secondary blow flies. Formulations containing lindane have recently been recommended for controlling these insects. (See E-813.)

Common Cattle Grub

Benzene hexachloride has given some kill of the common cattle grub (Hypoderma lineatum (De Vill.)). Its performance is erratic, however, and available formulations cannot be depended upon to provide satisfactory control at concentrations that are considered feasible from the standpoint of economy or safety. Regular spraying of cattle at 2-week intervals during the heel fly season, with preparations containing about 0.06 percent of the gamma isomer did not prevent animals from becoming infested with cattle grub larvae.

Chlordane

Chlordane has been employed extensively for the control of certain household pests, and is also being used against various insects and ticks affecting livestock. Rather extensive tests have been conducted with this insecticide against most of the major pests of livestock.

Chlordane is a viscous liquid, readily soluble in a number of solvents. Both wettable-powder preparations and emulsions have been used. Under some conditions this insecticide acts as a fumigant as well as a contact insecticide.

Cattle Lice

Chlordane, in both wettable-powder (50-percent) and emulsion-concentrate (25- to 50-percent) formulations, has been found to be equal to or more effective than DDT for controlling several species of lice on cattle. Complete control of both long-nosed and short-nosed lice was obtained with 0.5-percent sprays. A 0.25-percent spray gave good but not complete control of lice with one treatment. The cattle tail louse also appeared to be as susceptible to chlordane as to DDT. However, an insufficient number of tests have been conducted to determine the value of chlordane in practical control.

Goat Lice

Chlordane and DDT were found to be equally effective against red and yellow goat lice in tests conducted in Texas. A single treatment in 0.1- to 0.25-percent chlordane dips, prepared from either wettable powder or emulsifiable concentrate, provided complete control, and no reinfestation occurred for at least 4 months. At 0.05-percent concentration both materials controlled all motile forms, but some animals were found infested when examined 4 months later.

Hog Louse

In one test with a few animals chlordane gave apparently complete control of hog lice when applied as a wettable-powder spray at 0.2-percent concentration. DDT in the same test gave good initial control, but a few lice were found after 3 weeks.

Sheep Tick

Dips containing 0.05, 0.2, and 0.5 percent of chlordane gave complete control of sheep ticks. DDT also gave complete control, but chlordane eliminated the insects more quickly. When applied as a spray at 0.2- to 0.5-percent concentration, chlordane was superior to DDT and comparable with benzene hexachloride at 0.025 to 0.05 percent gamma-isomer concentration.

Lone Star Tick

Chlordane has been tested against the lone star tick on goats and cattle at concentrations of 0.25, 0.5, 0.75, and 1.5 percent. All concentrations gave complete or almost complete control of the flat stages, and the 0.5- and 1.5-percent concentrations gave nearly complete kill of all stages. DDT failed to kill all the engorged forms at 1.5-percent concentration. At the same concentrations the two insecticides gave about equal protection against reinfestation. (The performance of DDT in these tests has been mentioned on page 4.)

Gulf Coast Tick

Limited investigations indicate that the Gulf Coast tick and the lone star tick are about equally susceptible to chlordane, both from the standpoint of initial and residual toxicity.

Winter Tick

Chlordane is distinctly superior to DDT against the winter tick on cattle and horses. Complete or nearly complete control of all stages has been obtained with 0.5-percent sprays, whereas DDT at 1.5 percent killed only a small percentage of the engorged forms. Chlordane also gives better protection against reinfestation. At 0.5 and 0.75 percent chlordane prevented reinfestation for about 2 months as compared with 1 month for DDT. Chlordane as a 5-percent dust has also proved superior to DDT.

Flies

Chlordane has been tested on animals exposed to horn flies in cages, and has also been used in field tests on dairy animals in Texas and beef animals in Kansas. The tests in Kansas were conducted in cooperation with the State experiment stations and colleges of Kansas and Missouri and the Livestock Loss Prevention Board of Kansas City. Wettable-powder sprays at concentrations of 0.25 and 0.5 percent, applied at the rate of approximately 2 quarts per mature animal, gave good control of horn flies and protected the animal for about 3 and 4 weeks, respectively. There was no clear-cut difference in effectiveness between DDT and chlordane, although chlordane appeared to be slightly inferior.

Chlordane is more toxic than DDT to house flies. Its residual action is long lasting but not equal to that of DDT. In laboratory tests at Orlando, Fla., surface treatments with chlordane at the rate of 200 mg. per square foot, applied in acetone solution, gave complete or almost complete kill of flies exposed for 2 hours as long as 28 weeks after treatment. However, DDT was still completely effective against susceptible flies after 36 weeks, even at the low rate of 50 mg. per square foot. DDT-resistant flies are in general of normal susceptibility to chlordane. Field tests in Florida have shown chlordane to be one of the best substitutes for DDT against DDT-resistant flies. There is recent evidence, however, that house flies have developed resistance to chlordane where this insecticide is being used for fly control.

Chlordane applied at concentrations as high as 2 percent did not protect cattle from attack by tabanids, Tabanus abactor Philip, but it did cause 100 percent kill of feeding flies on the first day and 60 percent on the second day after treatment.

Screw-Worm and Fleece Worms

Chlordane is highly effective against screw-worm larvae, although it is not equal to lindane. Chlordane also protects sheep from attack by fleece worms when used in sprays containing 0.5 to 2 percent of the insecticide. In general, results have been comparable to those obtained with toxaphene.

Common Cattle Grub

When emulsions and wettable-powder suspensions containing up to 1.5 percent of chlordane were applied to cattle, either as a wash or with a high-power sprayer, the mortality of cattle grubs was less than 20 percent. Dusts containing up to 5 percent of chlordane also proved ineffective. Sprays containing 2 percent of chlordane applied to cattle at 2-week intervals apparently did not protect animals from attack by adults of the cattle grub, or heel flies.

Toxaphene

Toxaphene is one of the newest insecticides being offered to the public for livestock-pest control. It is a waxy material, with no objectionable odor, and readily soluble in most of the common solvents used in insecticide formulations, including petroleum oils. In most of the tests wettable powders and emulsion concentrates were used. The wettable powders contained from 25 to 40 percent of the toxicant, and the emulsion concentrates from 25 to 65 percent, with xylene or kerosene as the solvent.

Cattle Lice

When tested as sprays at concentrations of 0.25 and 0.5 percent, toxaphene gave results that were comparable with those obtained with DDT and chlordane against both short- and long-nosed cattle lice and the cattle tail louse.

Goat Lice

Toxaphene was at least equal, and perhaps superior, to DDT and chlordane against red and yellow goat lice. In limited tests apparently complete control was obtained with dips containing 0.05 percent of the insecticide. Dips at 0.1- to 0.25-percent concentration have kept goats free of lice for at least 4 months.

Hog Louse

Only one test, on a few animals, has been run with toxaphene against the hog louse. A wettable-powder spray at 0.2-percent concentration gave apparently complete control of the lice, being superior to DDT and comparable with chlordane.

Sheep Tick

Against the sheep tick toxaphene was superior to DDT when used as either a dip or a spray, but it was less effective than benzene hexachloride or chlordane. In a few tests complete control was obtained with dips containing 0.05, 0.2, and 0.5 percent of toxaphene. However, its action appeared to be slower than that of the other insecticides.

Lone Star Tick

Toxaphene was superior to DDT and equal to chlordane, but less effective than benzene hexachloride, against the engorged forms of the lone star tick. Its residual effect provided protection against reinfestation

comparable with that given by DDT and chlordane. Sprays at 0.5-percent concentration gave control of all stages and good protection against reinfestation for 2 weeks.

Winter Tick

Toxaphene was superior to DDT and comparable with chlordane against the winter tick on cattle and horses, when employed as either a spray or a dust. Good control of all stages and protection against reinfestation for about 2 months were obtained with sprays containing 0.5 to 0.75 percent.

Gulf Coast Tick

Extensive tests indicate that the action of toxaphene against the Gulf Coast tick is similar to that against the lone star tick. Good control of all stages resulted when cattle were dipped or sprayed with 0.5 percent of the insecticide. Good protection against reinfestation was obtained for 2 to 3 weeks, depending on the abundance of ticks. DDT was less effective than toxaphene in killing the engorged ticks, but the degree of protection was similar to that obtained with toxaphene. A spray containing 0.5 percent of toxaphene appeared to be comparable to one containing 0.025 percent of the gamma isomer of benzene hexachloride and 0.5 percent of DDT.

Cattle Fever Tick

In extensive tests conducted in South America[1/] sprays containing 0.5 percent of toxaphene were highly effective against all stages of the cattle fever tick present on animals. Complete protection was obtained for 3 weeks and good control for 4 weeks. Protection after 3 weeks was comparable with that obtained 11 to 13 days after treatment with a spray containing 0.025 percent of the gamma isomer of benzene hexachloride and 0.5 percent of DDT.

Ear Tick

Toxaphene was superior to DDT and comparable with chlordane and benzene hexachloride for controlling the ear tick. Good control for 2 to 3 weeks or longer was obtained with 0.5-percent toxaphene sprays applied in ears of infested cattle.

1/ These tests were conducted by E. W. Laake, of this Bureau, while on leave as a consultant for the American International Association for Economic and Social Development.

Flies

Toxaphene at 0.5-percent concentration has given control of horn flies similar to that given by DDT, although it is somewhat slower in killing flies coming to treated animals, and under certain conditions might appear to be inferior.

Toxaphene is less effective than DDT against house flies, from the standpoint of both initial and residual action. Toxaphene as a 2-percent spray did not protect animals from attack by tabanids or stable flies.

Screw-Worm and Fleece Worms

Toxaphene is fairly effective against screw-worms and fleece worms. It provided excellent protection against fleece worm attack on sheep when used at concentrations of 0.5 to 2 percent. Against screw-worms, toxaphene is considerably less effective than lindane.

Common Cattle Grub

In small-scale tests toxaphene did not control larvae of the common cattle grub. A 2-percent emulsion spray applied to cattle at 2-week intervals failed to prevent infestations.

Methoxychlor

Methoxychlor is similar to DDT in both physical and chemical properties. Most of the tests have been made with 50-percent wettable powders and 25-percent emulsion concentrates. In general the wettable-powder preparations seem to be somewhat more effective than the emulsions.

Cattle Lice

Sprays containing 0.5 percent of methoxychlor gave good control of short-nosed and long-nosed cattle lice. Methoxychlor also gave results comparable with those of DDT for controlling the cattle tail louse.

Hog Louse

Methoxychlor was effective against the hog louse and comparable with DDT, but a single treatment with 0.2-percent spray did not give complete control.

Sheep Tick

In tests in Oregon methoxychlor controlled the sheep tick when used as a wettable-powder dip containing 0.2 and 0.5 percent of the insecticide. Methoxychlor appeared to be slightly less effective than DDT.

Ticks

Against ticks methoxychlor was less effective than the other chlorinated hydrocarbon insecticides. Wettable-powder sprays in strengths up to 1.5 percent did not kill unengorged or engorged winter ticks or lone star ticks on cattle and horses, and animals became reinfested by the second week.

Flies

Methoxychlor gave good control of the horn fly on cattle. In some tests it gave results superior to DDT; in others the duration of effectiveness was shorter. A wettable-powder spray containing 0.5 percent of methoxychlor applied to dairy cattle in Texas and to beef cattle in Kansas at the rate of 2 quarts per mature animal provided 20 to 24 days' protection, as compared with 28 to 30 days for DDT. In other tests, conducted in Missouri and Kansas in cooperation with the State experiment stations and the National Livestock Loss Prevention Board, longer protection was obtained with methoxychlor. When treated animals were exposed to flies in cages, this material was slightly inferior to DDT in lasting effect.

Methoxychlor has shown some promise for control of the stable fly. In cage tests a wettable-powder spray containing 0.5 percent of methoxychlor applied to cattle prevented feeding by stable flies for several days and killed most of the flies that took blood during the first week after treatment. When applied to cattle in practical control tests, it reduced fly attack, but some flies fed on the first day of treatment. Most of the flies feeding during the first 3 days were killed. DDT at the same concentration did not prevent flies from feeding but killed most of the flies that took blood during the first 3 days after treatment.

Under laboratory conditions methoxychlor applied as a residual spray is almost equally as long lasting as DDT against both the house fly and the stable fly. Treated screen-wire cages exposed to sunshine and weathering remained toxic to stable flies longer than similar cages treated with DDT. Recent tests have shown that DDT-resistant house flies are also partially resistant to methoxychlor. In Florida, Texas, and Georgia erratic results were obtained with methoxychlor as a residual treatment for controlling house flies strongly resistant to DDT.

TDE

TDE (also called DDD) is another crystalline substance closely related to DDT in chemical and physical properties. The formulations used are also similar to those of DDT. Tests conducted with both emulsions and wettable-powder suspensions have thus far shown no difference in effectiveness.

Cattle Lice

TDE was about equal to the other chlorinated insecticides in effectiveness against short-nosed and long-nosed cattle lice. A 0.5-percent spray thoroughly applied gave good control of these insects. In preliminary tests TDE was also comparable with DDT for the control of the cattle tail louse.

Hog Louse

In preliminary tests run on a few hogs TDE was equal to DDT in initial kill of the hog louse. Neither material gave complete control at 0.2-percent concentration.

Sheep Tick

TDE gave good control of sheep ticks when employed as a dip at concentrations of 0.2 and 0.5 percent. It was about equal to methoxychlor but less effective than the other chlorinated hydrocarbon insecticides.

Ticks

In laboratory dipping tests against the lone star tick TDE was not so effective as chlordane, benzene hexachloride, toxaphene, or DDT.

In a limited number of tests against the winter tick TDE was approximately equal to DDT but inferior to toxaphene and chlordane. Sprays containing 0.5 to 0.75 percent of TDE did not kill engorged ticks but prevented reinfestation for about 1 month.

Flies

TDE gave satisfactory control of horn flies on beef and dairy animals. In general at 0.5-percent concentration in a wettable-powder suspension this material was about equal to methoxychlor and slightly less effective than DDT or toxaphene.

In laboratory tests TDE was less effective than DDT against the house fly. Preliminary tests in the laboratory and on caged cattle indicated that TDE was comparable with DDT in effectiveness against the stable fly.

Piperonyl Butoxide

Piperonyl butoxide alone is somewhat insecticidal, but it is of chief interest for use in combination with pyrethrum, which is widely used in fly sprays. The insecticidal action of pyrethrum is rapid and it is safe for use on warm-blooded animals, but it is costly, particularly for use on range animals. The addition of piperonyl butoxide permits reduction in the amount of pyrethrum required to control certain insects.

Pyrethrum plus piperonyl butoxide applied as a residual spray did not control house flies in dairy barns for more than 1 week. Piperonyl butoxide, however, greatly increased the toxicity of pyrethrum against house flies when used as a space spray.

Emulsions containing 0.005 percent of pyrethrins and 0.05 percent of piperonyl butoxide, or 0.01 percent of pyrethrins and 0.1 percent of piperonyl butoxide, gave complete initial control of the short-nosed cattle louse, but young lice were present on treated animals after 2 weeks.

Sprays containing 0.1 percent of pyrethrins and 1 percent of piperonyl butoxide protected animals against stable flies for 2 to 6 days. Some protection against tabanids was also indicated, although results reported by several investigators vary considerably. In some tests horse and deer flies fed on treated animals within 2 days after treatment, whereas in other tests almost complete protection was obtained for 3 to 4 days.

TOXICOLOGICAL INVESTIGATIONS

The toxicological effects of insecticides on man and animals are of primary consideration in connection with their use for the control of livestock pests. Some of the insecticides might prove hazardous to persons handling them and if they are employed in excessive amounts or if improperly formulated and mixed, there is danger that some of them will cause harmful effects or even death when applied to livestock. However, other, more complex toxicological problems arise in connection with their use. When some of the insecticides are applied to livestock, small amounts appear in the milk; and heavy and repeated applications of all the chlorinated hydrocarbon insecticides cause the storage of chemicals in the fatty tissues. When applied on cattle at the concentrations and frequency usually employed for controlling livestock pests, these insecticides differ considerably in the amount of chemical stored in fat or excreted in milk.

It has recently been found that appreciable amounts of DDT or TDE may appear in the milk of animals in dairy barns that have been treated with these insecticides.

The occurrence of these insecticides in milk is a matter of considerable concern, even though the quantity may be small. Milk is a major item of the diet of infants, children, and many convalescent persons of all ages. Studies conducted by the Food and Drug Administration during the last several years have led to the conclusion that even small amounts of DDT could in time prove hazardous to man when consumed in the diet. A recent statement by that agency follows:

> The Food and Drug Administration has the duty of protecting the inter-State food supply from adulteration. DDT is a poison and its use under conditions which would contaminate milk--a food so universally used by infants and children--would be contrary to the Food, Drug, and Cosmetic Act.

Current recommendations for the control of livestock pests take into consideration all available information on the toxicity of the insecticides to livestock and the amount of the residues appearing in meat and milk.

The Food and Drug Administration has investigated the toxicology of the various new insecticides to laboratory animals. The information given here is taken for the most part from papers by A. J. Lehman (1, 2), pharmacologist of that Administration. The data represent general averages for several kinds of animals. Chemicals of high purity, rather than the technical grades, were usually employed. Since some of the studies are incomplete and many of the formulations differ from those commonly employed in treating livestock, the information indicates trends or approximate toxicity only. The Bureau of Entomology and Plant Quarantine, in cooperation with the Bureau of Animal Industry and the Texas Agricultural Experiment Station, conducted most of the toxicological studies on livestock that are reviewed in this report. Most of these studies were carried out at Kerrville, Tex., with funds provided under the Research and Marketing Act of 1946.

The toxicological investigations on livestock have included studies to determine (1) the effects on livestock of various insecticidal chemicals and formulations of them when applied externally, (2) the amount of insecticidal chemical secreted in milk when insecticides are applied to dairy animals in amounts and frequency necessary to control horn flies and other parasites, (3) the amount of milk contamination resulting from the application of residual insecticides in dairy barns, and (4) the amount of insecticidal chemical stored in fat when the insecticides are applied in amounts and frequency necessary to control livestock pests. Some studies and observations have also been made to determine whether products from animals treated with benzene hexachloride are tainted with its odor or taste.

DDT

The mean lethal oral dose of DDT to laboratory animals is about 250 mg. per kilogram of body weight. From the standpoint of chronic toxicity, the Food and Drug Administration reports evidence of damage to the liver of certain laboratory animals that are continuously fed a diet containing 5 p.p.m. of DDT.

When applied externally, DDT in dry form shows no gross toxic effects on laboratory animals. In solution, animals can tolerate a single application to the skin of 3 grams per kilogram. However, repeated exposures to DDT in solution increase the hazards of DDT because it is readily absorbed and stored in tissues.

As many as 10 applications of a 2-percent DDT wettable-powder spray at 2-week intervals have produced no visible gross toxic effects on cattle. Single treatments with wettable-powder sprays containing as much as 8 percent of DDT can be tolerated without apparent harm to cattle. No adverse effects have been noted with xylene-type emulsions containing DDT at the same concentrations. However, certain solvents have produced harmful effects when used in emulsions, and the presence of DDT might increase the toxicity of such formulations.

Analyses have been made of many samples of milk taken from dairy cattle treated with DDT for fly control. In 1947 weekly samples of milk were analyzed from two herds near Kerrville, Tex., that had been treated with 0.5-percent DDT wettable-powder spray for controlling horn flies. Four treatments were made about 1 month apart. DDT was found in all samples of milk. The amounts ranged from 0.1 to 2 p.p.m., and averaged between 0.6 and 0.7 p.p.m.

In 1948 similar analyses were made of the milk from four herds in the Kerrville area. The animals were treated as often as necessary to control horn flies, with 1 to 2 quarts of a 0.5-percent DDT spray made from a concentrate containing DDT, xylene, and Triton X-100. The amount of DDT in the milk was somewhat less than in 1947, averaging about 0.25 p.p.m.

In another experiment several dairy cows maintained under controlled conditions were treated four times at 1-month intervals with a 0.5-percent DDT wettable-powder spray. The DDT in the milk averaged about 1 p.p.m. during the test period. The barns were also treated with a DDT emulsion at the concentration and frequency necessary for controlling house flies. The amount of DDT appearing in the milk after barn spraying increased in some cases for a day or two, but it quickly dropped to that present after DDT had been applied to the cattle. However, the barn sprayings did not always cause an appreciable increase in the DDT content of the milk. DDT in the milk attributed to barn sprayings occurred in four of eight sprayings. The amount attributed to barn treatment in

one case was approximately 1.23 p.p.m. on the day after the spraying, but dropped to about 0.25 p.p.m. on the second day. The average for the season was calculated to be about 0.1 p.p.m.

Special tests were conducted at Kerrville, Tex., and Beltsville, Md., in cooperation with the Bureau of Dairy Industry and the Food and Drug Administration to determine the degree of milk contamination resulting from barn-spraying alone. DDT appeared in the milk from the herds in all instances where feed and watering troughs were not covered. When the troughs were covered or washed out with water from a pressure hose before the spray dried, there was little contamination of milk with DDT. However, detectable amounts of DDT (less than 0.5 p.p.m.) were sometimes found even when these rigid precautions were taken.

Considerable information has been obtained on the storage of DDT in the fat of beef cattle treated with this insecticide for insect control. In one experiment four Hereford cows, each with a suckling calf, were treated five times at 28-day intervals with a 0.5-percent wettable-powder spray, and four others with a 0.5-percent emulsion spray. Two of the calves in each group were also sprayed. Two weeks after the fifth spraying fat samples from the cows treated with wettable-powder spray averaged 14.6 p.p.m. of DDT, and those from cows treated with the emulsion averaged 15.2 p.p.m. The four calves treated with the sprays averaged 52.4 p.p.m. of DDT; those not sprayed but which consumed milk from sprayed mother cows averaged 26.5 p.p.m.

Yearling Hereford steers sprayed four times at 3-week intervals with 0.5-percent DDT emulsion were biopsied at intervals during the period of treatment. Fat from three animals showed an average DDT content of 18 p.p.m. after one treatment, 31.2 p.p.m. after two treatments, and 32.8 p.p.m. after four treatments. In other tests four yearling Herefords were treated once with the same spray. Fat samples taken subsequently averaged 11.2 p.p.m. of DDT after 2 weeks, 8.1 p.p.m. after 6 weeks, 5.3 p.p.m. after 10 weeks, and 2.9 p.p.m. after 22 weeks.

Benzene Hexachloride and Lindane

The different isomers of benzene hexachloride vary in their toxicity to higher animals. For the gamma isomer the mean lethal dose to laboratory animals, when administered by mouth, is approximately 125 mg. per kilogram of body weight. In oil solution it is readily absorbed through the skin; when it is administered in this way, the mean lethal dose ranges from 20 to 50 mg. per kilogram. The Food and Drug Administration has found the gamma isomer of benzene hexachloride to be about one-fourth as toxic as DDT from a chronic standpoint, and that there is less tendency for storage of this chemical

in animal fat and it is more quickly eliminated. However, that agency considers the beta isomer of benzene hexachloride to be especially hazardous from the standpoint of chronic toxicity; therefore, this isomer should be eliminated from benzene hexachloride insecticides. Although the alpha and delta isomers are similar to the gamma in chronic toxicity, they should also be eliminated insofar as possible, since they increase the toxicity hazard and add little to the effectiveness of benzene hexachloride insecticides.

At Kerrville high concentrations of benzene hexachloride and frequent treatments were tested to gain information on the upper limits of toxicity. When mature or nearly mature animals were employed, no harmful effects were noted on 8 sheep, 8 goats, 4 cattle, 2 horses, and 2 hogs treated eight times at 4-day intervals with a dip or spray containing 1.5 percent of technical benzene hexachloride (0.15 to 0.18 percent of the gamma isomer). A wettable-powder preparation was used on some of the animals and a xylene emulsion on the others. The Livestock Loss Prevention Board of Kansas City obtained similar results on 8 animals treated with a wettable-powder spray at the same concentration. At Kerrville 10 cows treated nine times at 2-week intervals with a wettable-powder spray containing 2 percent of benzene hexachloride (about 0.24 percent of the gamma isomer) showed no apparent harmful effects. However, when a wettable powder containing 50 percent of gamma benzene hexachloride was used, all 3 cattle treated once with a spray containing 1.5 percent of the gamma isomer were killed, but 1 out of 3 receiving a spray containing 0.75 percent of gamma died and another was seriously affected but recovered. A 0.25-percent gamma spray had no ill effects.

Calves less than 3 months old are much more susceptible to benzene hexachloride than are cattle a year old or older. Tests have not been run to determine the relative susceptibility of calves less than 3 months and those 3 months to 1 year old. Emulsion sprays containing 0.05 percent of the gamma isomer and xylene as the solvent killed 3 of 11 Jersey calves that were thoroughly saturated to simulate dipping. Wettable-powder sprays of the same gamma content were apparently less toxic, but toxic symptoms were evident in 2 of 9 calves treated and 1 calf died.

Recently tests have been conducted with lindane, the essentially pure gamma isomer of benzene hexachloride. Eight Jersey calves were sprayed with an emulsion containing 0.05 percent of lindane. Only one calf showed toxic symptoms, and it recovered. Of four sprayed with 0.1 percent of lindane, one died, one showed toxic symptoms but recovered, and two were unaffected. Two Hereford calves given the same treatment showed no adverse effect. Apparently the toxicity of lindane to calves depends on the breed and perhaps other factors. Tests on

calves were made with three samples of benzene hexachloride of different gamma content--namely, 12, 36, and 95 percent. When diluted to the same gamma content, all three sprays were equally toxic.

Some reports have been received of death or injury to calves or cattle treated with benzene hexachloride or lindane for pest control. It has been difficult to determine what concentrations were used when death occurred. These experiences emphasize, however, that the insecticide should be used with care to avoid injury to cattle, particularly to calves.

Suckling pigs and lambs appear to be much more resistant than calves to lindane sprays. In a limited number of tests 0.5-percent lindane did not harm suckling pigs and lambs about 6 weeks old.

Only limited information is available on the storage of benzene hexachloride in fat of livestock treated for pest control. A spray containing 0.25 percent of the insecticide (approximately 0.03 percent of the gamma isomer) was applied to 8 yearling Hereford cattle at 2-week intervals for 12 treatments. Two weeks after the last treatment fat samples taken from these animals had an average organic-chlorine content equivalent to 31 p.p.m. of benzene hexachloride; a month later it dropped to 11 p.p.m. and after another month had returned to normal. Six yearlings were sprayed with 0.025-percent lindane emulsion at 3-week intervals over a period of 6 months. No lindane was found in fat samples taken at intervals during the treatment period.

To determine whether the use of benzene hexachloride gave off-flavor or odor to meats of treated animals, tests were conducted with several kinds of animals. One pig received two thorough treatments 9 days apart with a spray containing 2.5 percent of benzene hexachloride (0.3 percent of gamma isomer). The animal was killed 2 days after the second treatment, and 10 families cooked and tasted the meat. None of the families detected benzene hexachloride taste, but two of them detected the odor while the meat was cooking. Another pig was sprayed twice 4 days apart with 1.5 percent of benzene hexachloride, and slaughtered on the sixth day. None of the families eating the meat reported benzene hexachloride odor or taste. In similar tests with a goat, a sheep, and a yearling calf, one report of benzene hexachloride flavor or odor from each animal was received. Another calf and a pig sprayed eight times at 4-day intervals with 1.5 percent of benzene hexachloride (0.18 percent of gamma isomer) and slaughtered 1 month after the last treatment showed no marked off-flavor or odor, although some individuals gave positive reports. In tests with six chickens exposed for one to several weeks to roosts heavily painted with a slurry of benzene hexachloride (12 percent gamma), conflicting reports were received, but in one chicken marked benzene hexachloride odor was detected. In these tests the concentration of benzene hexachloride was in excess of that needed for controlling parasites.

In an experiment conducted in cooperation with the Missouri Agricultural Experiment Station, no off-flavor or odor was detected in meat from a cow dipped 18 times over a period of 2 years in a wettable-powder suspension containing 0.5 percent of benzene hexachloride (0.05 percent of the gamma isomer).

No reports of off-flavor or odor of meat from livestock treated with benzene hexachloride for practical pest control have come to the attention of this Bureau.

Chlordane

The acute toxicity of chlordane administered orally to laboratory animals is reported to be about half that of DDT. However, the toxicity of a solution applied repeatedly to the skin is reported to be greater for chlordane. From a chronic-toxicity standpoint this insecticide is considered by the Food and Drug Administration to be about four times as toxic as DDT, when taken in the diet of animals.

At Kerrville five sheep and five goats were dipped, and two cattle and one horse were sprayed eight times at 4-day intervals with a 1.5-percent chlordane emulsion, and the same numbers of animals were treated with a wettable-powder preparation at the same strength. The test was repeated with a new lot of chlordane, but only five sheep and two pigs were treated with each preparation. In the first test none of the cattle or horses were killed with either preparation, but the five sheep and two of the goats were killed by the emulsion and two sheep and two goats by the wettable-powder suspension; some of the animals died after the third treatment. In the second test none of the animals were killed.

The Livestock Loss Prevention Board obtained similar results in that sheep were killed by the severe treatment, and one of two cattle sprayed with each preparation was killed.

In another test at Kerrville 3 of 10 cattle died after four thorough treatments at 2-week intervals with a 2-percent wettable-powder preparation. No explanation can be offered for the variable results.

Eight yearling Herefords were sprayed 12 times at 2-week intervals with a 0.5-percent chlordane emulsion. The animals showed no toxic symptoms, and weight gains equaled those of untreated animals.

Tests on a few young calves 2 to 6 weeks old indicate that chlordane is about as toxic as toxaphene when single applications are made. Of 10 calves sprayed with a 1-percent emulsion, 1 died and 9 showed no toxic symptoms. Of 10 calves sprayed with a 2-percent emulsion, 4 died and 6 showed no toxic symptoms. Suckling pigs and lambs are much more resistant than calves. An emulsion dip containing 4 percent of chlordane did not adversely affect 2 pigs, 2 lambs, or 4 kids.

Weekly analyses of milk samples from two dairy herds treated with 0.5-percent chlordane wettable-powder spray four times at intervals of about 1 month showed that small amounts of organic chlorine were present in the milk. Of 18 samples analyzed, 17 showed from 0.1 to 0.4 p.p.m. of organic chlorine. However, it is not certain that all the organic chlorine present can be attributed to the chlordane treatment.

To obtain information on the storage of chlordane in treated livestock, fat samples were taken from the eight yearling Hereford cattle treated 12 times with a 0.5-percent chlordane emulsion. Analyses of samples taken 2 weeks after the last treatment showed organic-chlorine content equivalent to 20 p.p.m. of chlordane. One month later this figure had dropped to 4 p.p.m. and after another month the organic chlorine was normal.

Three yearling steers were sprayed once with a 0.5-percent chlordane emulsion. Two weeks later the fat averaged 9.1 p.p.m. of organic chlorines compared with 6.5 p.p.m. prior to treatment. Because of wide variations in the normal level of organic chlorine, the difference probably can not be considered significant.

Toxaphene

Toxaphene is reported to be about four times as toxic as DDT when administered orally to laboratory animals, the mean lethal dose being about 60 mg. per kilogram. It is also more toxic than DDT when applied to the skin. The Food and Drug Administration considers toxaphene to be about as toxic as lindane, or one-fourth as toxic as DDT, from a chronic standpoint when consumed in the diet.

At the Kerrville laboratory 20 sheep, 15 goats, 8 cattle, 4 horses, and 4 hogs, all mature or nearly mature, were treated eight times at 4-day intervals with 1.5 percent of toxaphene. No adverse effects were noted on any of the animals.

Mature animals showed no ill effects from single applications of emulsion sprays containing 8 percent of toxaphene. Young calves, however, are more susceptible. After reports were received from Texas that toxaphene caused the death of some calves that had been dipped in this insecticide, tests were made on calves 1 to 2 months old. A single spraying with 1.5-percent toxaphene emulsion (containing xylene or kerosene) or wettable-powder suspension caused toxic symptoms in some of the calves, and two treatments 4 days apart caused a few deaths. Eleven Jersey calves were thoroughly treated with 1-percent toxaphene sprays, eight with a kerosene emulsion and three with a wettable-powder suspension. One of the calves showed toxic symptoms but recovered; the rest showed no harmful effects. A single treatment at 0.75-percent concentration had no adverse effect on 12 calves. After being treated

eight times at 4-day intervals one calf showed symptoms of poisoning but recovered. Suckling pigs and lambs are much more resistant than calves.

Field observations indicate that deaths among cattle treated with sprays or dips containing 0.5 percent of toxaphene are due in part, if not entirely, to the use of faulty formulations.

Milk samples from dairy herds treated four times at about monthly intervals with wettable-powder sprays containing 0.5 percent of toxaphene were analyzed for organic-chlorine content. Of 43 samples analyzed, 27 were negative. In the samples giving positive results, the amount of organic chlorine ranged from 0.2 to 0.6 p.p.m. It is not certain whether the organic chlorine present can be attributed to the toxaphene.

To determine whether toxaphene applied repeatedly to cattle will increase the organic-chlorine content of fat, 36 yearling Hereford steers were sprayed from 1 to 12 times at 2-week intervals with a 0.5-percent toxaphene emulsion. There was no clear-cut evidence that the organic-chlorine content increased significantly over that of untreated cattle, but at no time did it exceed the equivalent of 5 p.p.m. of toxaphene. In 8 similar animals on range grass that were similarly treated, 2 weeks after the last treatment the organic-chlorine increase over untreated animals was equivalent to 8 p.p.m. of toxaphene. Four weeks later the organic-chlorine content returned to normal.

Methoxychlor

Methoxychlor is the least toxic of the chlorinated hydrocarbon insecticides that have been investigated. The mean lethal dose to laboratory animals when administered orally is reported to be higher than 6 grams per kilogram of body weight. The Food and Drug Administration has also found methoxychlor to be of low toxicity when fed in the diet to laboratory animals. From results of tests of single and repeated applications of methoxychlor in solution to the skin of laboratory animals, this insecticide is the least toxic of the new insecticides, including piperonyl butoxide. On the basis of tests on laboratory animals, the toxic dose is estimated to be about 2,800 mg. per kilogram of body weight for single exposure and 600 mg. per kilogram when applied repeatedly.

At Kerrville no adverse effects were noted when sheep, cattle, hogs, and horses were treated repeatedly with emulsions or wettable-powder preparations containing up to 2 percent of methoxychlor. Single applications of up to 8 percent of methoxychlor showed no adverse effects on young calves.

Milk samples collected at weekly intervals from two herds of dairy cattle treated five and six times during the season with a wettable-powder suspension containing 0.5 percent of methoxychlor were analyzed for organic-chlorine content. Only 3 of 42 samples analyzed showed organic chlorine (0.1 p.p.m.). A single spraying with 0.5-percent

methoxychlor emulsion resulted in an average deposit of 2.8 p.p.m. of methoxychlor in the fat of four yearling Herefords, when determined by a method specific for this insecticide. When the same spray was applied to three similar cattle twice 2 weeks apart, the methoxychlor content averaged 1.5 p.p.m. after each treatment.

TDE

The mean lethal oral dose of TDE for several laboratory animals is reported to be about 2.5 grams per kilogram of body weight. The Food and Drug Administration considers TDE to be somewhat less toxic than DDT from the chronic standpoint.

At Kerrville sheep, goats, cattle, hogs, and horses showed no ill effects when treated eight times at 4-day intervals with 1.5-percent TDE emulsions or wettable-powder preparations. Single applications in strengths as high as 8 percent have shown no adverse effects on young calves.

In 1947 samples of milk taken at weekly intervals from two herds of dairy cattle treated with TDE were analyzed for their TDE content by the colorimetric method. The animals had been treated five times with a 0.5-percent wettable-powder spray (approximately 2 quarts per animal). Of 20 samples analyzed, 8 were negative and 12 showed TDE present in amounts ranging from 0.1 to 1.2 p.p.m. TDE in similar amounts was found in the milk taken from several herds treated in a similar manner during 1948. When applied to dairy barns, TDE appeared in milk in amounts at least equal to those obtained after barns had been treated with DDT; when applied to beef cattle, it was stored in about the same amounts as DDT. The stored chemical is persistent in the fat but seems to be eliminated somewhat more rapidly than DDT. Four Hereford cattle sprayed once with 0.5-percent TDE emulsion averaged 11 p.p.m. of TDE in the fat 2 weeks later. The amounts in the fat 6, 10, and 22 weeks after treatment averaged 5.2, 3.9, and 0.7 p.p.m., respectively.

Piperonyl Butoxide

The mean lethal dose of piperonyl butoxide administered by mouth to various laboratory animals is reported to be about 13 grams per kilogram of body weight. On the basis of applications to the skin of laboratory animals, the toxic dose averages about 1.8 grams per kilogram for single exposures and 200 mg. per kilogram for repeated applications. Pyrethrum, with which this material is usually combined, alone is also relatively nontoxic to warm-blooded animals, especially in the small amounts generally applied. However, the medium lethal single dose of pyrethrins applied orally is about 1.5 grams per kilogram.

SUGGESTIONS REGARDING THE USE OF THE NEW INSECTICIDES

This publication does not give detailed directions for controlling various livestock pests with insecticides. Rather, it contains suggestions or recommendations on the field of use for the new insecticides in the light of current information on their performance and the potential hazards connected with their use. Livestock growers who contemplate employing any of the materials should consult with workers in their own States who are concerned with livestock-pest problems.

In view of the differences in toxicity of the various insecticides to higher animals and in their excretion in milk, the materials useful in controlling insects affecting dairy cattle should be considered separately from those that might be satisfactory for controlling pests of other kinds of livestock.

Precautions

Be extremely careful when storing, handling, mixing, and applying the insecticides discussed in this publication.

Store insecticides where children, pets, and other animals cannot reach them. Store those containing kerosene or xylene so that there will be no fire hazard, and do not mix or spray them in the presence of an open flame or sparks.

When handling, mixing, or applying insecticides, take proper precautions against unnecessary exposure to skin contact or breathing of spray mist. When applying sprays continuously and repeatedly, wear a respirator and clothing that protects the body. Change clothing frequently and, if it becomes saturated with spray, launder the clothing before it is worn again. Bathe or wash parts of the body with which insecticides have come in contact.

When applying insecticides take care to avoid accidental contamination of food and water for man and animals.

Observe carefully the suggested concentrations and rates of application. Mix the materials thoroughly and agitate them continuously in the spray tank. If an emulsion concentrate will not mix readily with water and an oily film accumulates, do not use the material.

Dispose of unused sprays in such a way as to avoid hazards.

In spraying dairy barns, take special precautions to avoid contaminating milk or utensils. Cover water cups and feed troughs, and cover or remove feed while spraying.

DDT

DDT applied to dairy animals may appear in milk in quantities judged by the Food and Drug Administration to be a potential hazard to consumers. It may also appear in milk when dairy barns are treated with the insecticide. The Bureau therefore recommends that this insecticide not be applied to animals producing milk for human consumption. Nor should DDT be used for fly control in dairy barns or milk-processing plants. The Bureau still recommends DDT as an aid in controlling flies in other places, and for controlling pests on livestock other than dairy animals producing milk for human consumption.

Benzene Hexachloride and Lindane

If benzene hexachloride is to be used for controlling any livestock pest, it is advised that wettable-powder formulations be used. Products of high gamma-isomer content are the least objectionable from the standpoint of odor. Lindane, the essentially pure gamma isomer, is recommended in preference to the technical product. Benzene hexachloride should not be applied to dairy animals. Neither should it be applied to meat animals that are to be slaughtered within 30 days. In view of its toxicity to calves, the gamma-isomer concentration of either product should not exceed 0.03 percent for controlling insects or ticks on them, and for cattle a year or older the maximum should be 0.05 percent. For tick control 0.025 percent of the gamma isomer plus 0.5 percent of DDT is suggested. For louse control on cattle 0.03 to 0.05 percent of gamma isomer is recommended. For control of sheep ticks on goats and sheep, a dip containing 0.025 percent or a spray containing 0.05 percent is suggested. For louse control 0.03 percent is usually enough, but to assure complete control, especially in recently shorn animals, 0.05 percent may be required. For control of lice on hogs, a concentration of 0.05 to 0.06 percent in a spray or dip is recommended.

Lindane is not recommended for repeated use on dairy cattle to control flies and ticks, although single treatments for louse control are recommended. Lindane is recommended as a residual treatment for spraying dairy barns or milk-processing rooms for fly control. A deposit of 25 mg. per square foot is suggested. For other farm buildings 25 to 50 mg. per square foot is suggested. A special preparation known as EQ-335 Screw-worm Remedy (see E-813), containing lindane, has recently been recommended for controlling screw-worms and wool maggots.

Chlordane

No harmful effects on livestock have been noted or reported when chlordane has been applied in insect-control operations. However, toxic effects have developed in experiments with 1.5- to 2-percent sprays applied repeatedly to livestock. There is also evidence of some storage of chlordane in fat of cattle when applied at 2-week intervals. Additional tests with repeated treatments at various concentrations should therefore be conducted before recommendations are made for its use for controlling pests on livestock, such as ticks and flies requiring repeated applications. There is no evidence, however, of toxic effects of single or occasional applications of 0.5-percent sprays. Therefore, single applications of 0.5-percent sprays are recommended for louse control on cattle and hogs. For controlling lice and sheep ticks on sheep and goats, 0.25-percent dips or 0.5-percent sprays are suggested. Sprays containing 0.5 percent of chlordane have also proved effective in preventing or controlling wool maggot infestations in sheep.

Chlordane has given good results against house flies in situations where adequate control cannot be obtained with DDT. However, the Bureau advises that it not be used for fly control in dairy barns, milk-processing plants, or similar situations.

Toxaphene

From the standpoint of economy and efficiency toxaphene is considered a good insecticide for the control of several livestock pests. Investigations have shown that this insecticide can be used safely as a spray when applied to livestock.

Toxaphene as a 0.5-percent spray, made from an emulsifiable concentrate or a wettable powder, is recommended for controlling horn flies, ticks, and lice on beef cattle; lice on sheep, goats, and swine; and for sheep ticks and wool maggots on sheep.

Because of the narrow safety margin of toxaphene, particularly for calves, the insecticide is not at present recommended for use as a dip for cattle. Investigations are under way to develop suitable dip formulations that will remain stable and disperse uniformly in vats. Toxaphene is recommended, however, for use as a dip at a concentration of 0.25 percent for controlling lice and sheep ticks on sheep and goats.

Until more information is available on the rate of excretion of toxaphene in milk of dairy animals treated for insect control, the Bureau recommends that it not be applied to dairy cows. The insecticide is also not recommended for fly control in dairy barns. For fly control in other farm buildings, the insecticide should be applied at the rate of 200 mg. per square foot.

Methoxychlor

Methoxychlor is recommended for controlling certain insects on dairy animals and other livestock. Results to date indicate that for horn flies and lice on cattle the insecticide compares rather favorably with DDT. It is suggested that cattle be treated with sprays containing not less than 0.5 percent of methoxychlor, preferably prepared from a wettable powder. For the control of horn flies, about 2 quarts of spray should be applied to a mature animal. If higher concentrations are employed the amount of spray should be reduced. For control of lice the animals should be thoroughly saturated. Against horn flies about 3 to 3 1/2 weeks' protection may be expected, as compared with about 4 weeks for DDT applied at the same rate.

For stable fly control on dairy cattle a tentative suggestion is to apply a 0.5- or 1-percent spray, preferably a wettable-powder preparation, once or twice a week to the legs, belly, and lower part of the sides of the animals. A light spraying on their backs at the same time will make further horn fly treatments unnecessary. Other cattle on the farm should also be treated at regular intervals for horn fly control.

For louse control on cattle and hogs a 0.5-percent concentration is recommended for most conditions. In the Southeast, where the cattle tail louse is prevalent, a spray containing 1 to 1.5 percent is recommended.

For controlling lice or sheep ticks on sheep and goats a dip containing 0.25 percent of methoxychlor is suggested.

Methoxychlor is recommended as a residual spray for fly control in farm buildings, including dairy barns. Results have been erratic due to resistance of flies to methoxychlor where resistance to DDT has developed. A wettable-powder or emulsion spray applied so as to deposit 200 mg. of methoxychlor per square foot is recommended.

TDE

TDE should not be used on dairy animals. It may be used to control horn flies on cattle and lice on cattle, swine, sheep, and goats. For controlling horn flies a 0.5-percent concentration applied as a wettable-powder or emulsion spray at the rate of 2 quarts per animal is suggested. For louse control the animal should be thoroughly saturated with a spray of the same concentration. If employed as a dip for controlling lice and sheep ticks on goats and sheep, a concentration of 0.25 percent is recommended.

New Pyrethrum Insecticides

Several new materials that increase the insecticidal effectiveness of pyrethrum are available, but piperonyl butoxide is the only one that has been investigated for controlling livestock pests. Because of the low toxicity of pyrethrum-piperonyl butoxide insecticides to animals,

no hazards should ordinarily be created by their use. (If used in an oil solution, excessive amounts of oil may prove harmful to the animals.) This insecticide preparation should be considered for the control of lice, horn flies, stable flies, horse flies, and deer flies on dairy animals. For louse control a thorough treatment with an emulsion or wettable-powder spray containing 0.025 percent of pyrethrins and 0.25 percent of piperonyl butoxide is suggested. For controlling horn flies, stable flies, and horse flies on dairy cattle, a spray containing 0.1 percent of pyrethrins and 1 percent of piperonyl butoxide should be applied at the rate of 1 quart per animal. This spray is also effective when applied as a mist for controlling flies in barns or on dairy cattle. A light mist applied at the rate of about 1 ounce per cow will control flies for several hours or until the next milking.

Other Methods of Controlling Dairy Pests

Various oil-base insecticides for application as a light mist have been employed extensively in the past to provide temporary control of flies on dairy cattle. These materials which contain pyrethrum, rotenone, or an organic thiocyanate, have also been used as space sprays in barns and elsewhere. They are again coming into wide use because of the restrictions placed on some of the newer insecticides and because of the occurrence of strains of house flies that are resistant to certain insecticides. However, there is danger of harming livestock by treatment with oil-base sprays. Such sprays are intended for use as mists only and in such small quantities that the skin of the animals does not become wet with the oil. The amount applied should not exceed 1 ounce per animal. When mist sprays are used on dairy cattle and in dairy barns, other cattle and other places on the farm where flies concentrate should be treated with residual sprays of the types discussed in this publication in order to reduce the over-all fly population to a practical minimum.

The use of insecticides should not be relied on to give complete insect control on the farm. Rigid sanitation, especially manure disposal, should be practiced to prevent fly breeding. Well-screened buildings will also aid in excluding flies and in preventing the contamination they may cause.

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